Janus: A Reconfigurable Testbed for the Evaluation of Hardware and Software Issues for an Electronic Book Reader

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ABSTRACT

With the recent market introduction of several new electronic book readers, issues remain regarding optimum control structure and the benefits of standards. Our lab has built a reconfigurable electronic book prototype that can be used to evaluate systems issues and support standards efforts. Hardware instrumentation will permit precise measurement of performance parameters.

I. INTRODUCTION

The concept of a dedicated electronic book reader device is not new; several generations of readers have come and (mostly) gone. What is new this time is an unprecedented level of interest and activity across the industry - the number of new reader devices announced and entering the market in the past twelve months, the involvement of publishers, the far-ranging plans for distribution of "E-Book" media, and the proposal (headed by Microsoft) for an "Open E-Book" standard [1]. Together with improvements in display and other enabling technologies, falling prices, and increasing consumer acceptance of the idea of an electronic book user interface, these give electronic book readers perhaps their best chance ever of widespread commercial success. With this sudden burst of activity, however, several issues have not been fully addressed: the relative efficiency of various possible user interface structures, the merits of various underlying control structures, and the testing of features of the proposed standard. The National Institute of Standards and Technology (NIST) has developed Janus, a reconfigurable prototype electronic book reader, which can be utilized in addressing these issues.

The Janus project began early in 1997, based on ideas by Victor McCrary, head of the Information Storage and Integrated Systems group, within the Information Technology Laboratory at NIST. Electronic book readers had very little market presence at that time, and one of the initial goals for the Janus project was to revive the concept of the electronic book reader by the introduction of new functionality. With the announcement of many new commercial devices, emphasis has shifted toward using Janus to facilitate the success of reader devices, as a service to industry and to consumers. Its high degree of reconfigurability and non-proprietary design make Janus particularly suitable for this role. This paper describes Janus, explains how it can facilitate both standards testing and evaluation of user interface structures and control structures, and finally lists planned modifications of Janus that will improve its functionality for these purposes.

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[1] Certain commercial products are identified here in order to document our experiments. Identification of such products does not imply endorsement by NIST.

II. THE JANUS ELECTRONIC BOOK READER

Briefly, the Janus electronic book reader is a prototype hardware device, based upon a specific design philosophy, in which hardware and software are combined to perform the functions (and exhibit most of the characteristics) of a working electronic book reader, with additional functions that make it particularly suitable as a testbed.

A. Janus design philosophy

The fundamental design philosophy for Janus is based on a simple set of underlying principles:

- **Ease of construction.** The prototype must be easy to construct, and utilize "off the shelf" hardware and software wherever this does not compromise the functionality to be represented.
- **Ease of modification.** The prototype must be designed so that both hardware and software can be quickly and easily modified, to simplify upgrades, and to allow a wide variety of tests.
- **Selectivity of features represented.** No effort is made to replicate all of the features of a portable electronic book reader. The most obvious example of this is portability; Janus is a desktop device, which greatly simplifies construction, and does not impact most of the functional tests. Janus is also not required to have the same processor, memory, and software structure as any specific commercial reader device. Its reconfigurability allows specific features to be modified until they are sufficiently close to replication of a desired condition, for any particular test.
- **Ability to perform actual functions.** In addition to its ability to facilitate testing and measurement, Janus should be able to function as a real, working electronic book reader. This serves as an important "reality check" in conducting tests.

B. Janus hardware

The Janus prototype is constructed as simply as possible, with a desktop personal computer as a controller (unusual only in that it has two graphics controller cards), two LCD screens as displays, and a touch screen interface on one of the LCD screens (with plans to add a second touch screen in the near future). Janus is designed to display two pages (comparable to the two visible pages of an open paper book), but it can also be programmed to replicate the functions of a single-page reader.

C. Janus software

Janus is currently programmed in Visual Basic, which contains features to support creation of graphical control structures. A future version may be programmed in Java, to facilitate experiments involving more advanced functions. A file format conversion from RTF to HTML/XML is in process, to permit advanced functionality, and to enable testing of some of the proposed features of the Open E-Book standard.

The software includes a table of commands, which are accessed by pressing a touch screen button or by verbal command. The details of the software implementation are responsible for underlying support functions, such as managing access to the book file,

and controlling the paging to maintain the proper relative positions of the two pages of text as the user progresses through the book or changes font size.

D. Janus functions

The Janus electronic book reader may be operated by touch screen, or by voice commands. A pop-up keyboard appears on the screen whenever entry of text is required. The reader functions currently implemented are:

- **Open, Close, Exit.** "Open" allows the user to select the book file and open it. "Close" closes the current book file. "Exit" terminates execution of the electronic book reader software.
- **Previous Page, Next Page.** The two displayed pages of the electronic book file shift in unison whenever the pop-up page control buttons are pressed. Additional control features handle page positioning at the beginning or the end of the book file.
- **Text selection.** The user can select a word just by touching it (thus placing the cursor in the word), and can select a block of text by touching and dragging a finger.
- **Underline/Bold.** Underline and bold font for selected text can be toggled on and off by repeatedly pressing the appropriate touch screen buttons.
- **Font size increase/decrease.** Two touch screen buttons are reserved for changing the font size of all text. Page boundaries within the text are automatically updated with the change.
- **Dictionary lookup.** A search is made for the selected word or phrase in a dictionary, and the definition given if found. The user also has the option to type in a word or phrase on a pop-up touch screen keyboard and ask for a definition. Future plans for Janus call for inclusion of both a dictionary and a glossary: the dictionary to be representative of a built-in dictionary in a commercial dictionary, and the glossary to represent a list of definitions that would come with a particular electronic book file. [For example, a novel based on nineteenth-century sailing ships would include terminology one would be unlikely to find in a small general-purpose dictionary – these terms would be included in a glossary shipped with that novel.]
- **Bookmark/Annotation.** The user can select a point in the text, a word or a phrase, and associate a bookmark with it. If desired, the user can also enter an annotation by means of a pop-up touch screen keyboard. The bookmarks and annotations are saved in a table, allowing the user to call up the table and jump to any of the selected points.
- **Search.** The user can select a word or phrase in the text, or type in a word or phrase on a pop-up virtual keyboard, and search for the next or previous occurrence in the text. "**Find Next**" can be used after a search string has been entered.

III. EVALUATION OF USER INTERFACE STRUCTURES

The user electronic book functions described in the previous section are arranged in a hierarchical command structure. Many are activated by a single touch of a touch screen button, while for others a sequence of user operations is required, for example opening

subsidiary sets of touch screen control buttons. The designers of the Janus prototype consider the current user command structure to be fairly logical for the functions required, but there would not be universal agreement on this particular command structure.

Fortunately, the reconfigurability of Janus permits alternative command structures to be implemented and tested. This method has already been employed on a subjective basis, as the current user interface has gone through several iterations during the design process. Alternative user interface command structures can be tried on test subjects, with subjective reports on preferences used as suggested guidelines for the design process of commercial devices. Quantitative tests can also be implemented, with records made of the rate of learning, and the speed with which a trained (or novice) user can perform specified functions. A detailed evaluation could include "time and motion" studies, to evaluate effectiveness of button placement, speed of comprehension of on-screen instructions, usability of the pop-up keyboard, and so on.

If it should be decided that uniformity of user interface is relevant to the content of an electronic book standard, this capability of the Janus testbed would become particularly relevant to the standards process.

IV. EVALUATION OF CONTROL STRUCTURES

In addition to the user interface, an electronic book reader has an underlying control structure by which it performs its functions. For example, the way in which text is selected from the electronic book file and made visible on the screen can be performed in a number of different ways. At a general level, this part of the reader design is “transparent” to the user interface, but it can affect performance (as shown by response time), and determine the resources (processor power, memory, etc.) that are needed to produce a given level of performance. The current Janus design also uses a particular control structure, which also can be modified, and the performance results compared to those of other control structures.

V. TESTING FEATURES OF THE PROPOSED E-BOOK STANDARD

Microsoft has proposed an Open E-Book standard, and a group is forming to undertake the development of this standard. Several companies have proposed that NIST participate in the development of this standard, in part by making available a testbed for evaluation of particular features of the proposed standard. Its high degree of reconfigurability qualifies the Janus prototype for this role. It is expected that during the development of the standard, feature issues will arise, and in many cases the Janus prototype can be temporarily reconfigured to test these features.

The applicability of numbers derived from experiments to commercial electronic book readers will have to be determined by actual testing. For commercial devices that do not permit access to control software, crude measures can be obtained by techniques such as timestamped videotaping of the reader display, to establish a framework for correlation of relative execution time.

VI. PLANNED MODIFICATIONS OF THE JANUS TESTBED

A number of modifications are currently planned or in process for the Janus testbed – several of these will facilitate Janus' role in performing these test and measurement functions:

- **Instrumentation.** A number of hardware probes are to be inserted into the architecture of the Janus electronic book. These probes can be used to monitor bus activity, graphics controller function, serial port activity, memory accesses, and so on. The specific nature of these probes will depend on the measurements needed. In effect, they will allow analysis of how effectively the system resources are being utilized (as a function, for example, of the current command control structure). The research group responsible for the Janus project has previously performed similar hardware instrumentation of parallel processor systems.
- **MultiKron hybrid performance measurement.** MultiKron [2,3] is the name of a VLSI performance measurement chip developed by another project group at NIST. MultiKron is a "hybrid" performance measurement device, permitting input from hardware probes, but ultimately controlled by small pieces of code inserted in the operating software of the device under test. These small pieces of test code instruct the MultiKron to capture the current status of the device under test, to add a precision timestamp, to create a "sample" structure, and to automatically store the sample in a dedicated memory area. Generally after the run of an experiment, the collected samples stored by the MultiKron are read out of the dedicated memory and subjected to analysis. In this way, highly detailed information on system performance can be extracted. In addition to the inclusion of data from hardware probes, MultiKron has the advantage (over pure software analysis) of perturbing system operation only slightly, due to the small size of the pieces of inserted code; MultiKron therefore produces very good accuracy in its performance measurements. MultiKron can be used for both "coarse-grain" measurements (e.g. time to look up a dictionary definition or advance to the next page), and "fine-grain" measurements (e.g. the time to execute a short sequence of machine-level commands). The MultiKron chip has been incorporated into a number of circuit boards, permitting direct backplane connection into a number of different system architectures. The inclusion of a MultiKron circuit board in the Janus prototype will greatly simplify the collection of data, allow identification of performance bottlenecks (as a guide to "tuning" of the system), and serve as a check on how well Janus is emulating the performance of commercial electronic book reader devices. A possible outcome of the use of MultiKron is a set of generic recommendations regarding control structures and the balance of system resources needed for a particular application.
- **Additional functionality.** While permitting testing of the features common to most of the existing electronic book readers, the Janus prototype retains the ability to serve as a testbed for newer features that may be implemented in future commercial devices. One of these features now planned for inclusion in Janus is "multimedia" capability – the ability to call up sound and animation when it is appropriate to the book being referenced. Aside from the obvious uses for entertainment, a serious application would be in a physics text, portraying the motion of objects to assist a description of kinetics. A second planned series of upgrades falls under the category of accessibility: the addition of voice output (but still allowing the user to move about

within the text of the electronic book and permitting the use of many of the advanced electronic book functions), and a current effort to create a Braille version of the electronic book interface. These additional features are likely to find applicability in evaluating the next generation of electronic book readers.

VII. CONCLUSION

The Janus prototype electronic book reader is now able to function as a working electronic book device. This capability serves as a valuable check on issues of functionality. Its high degree of reconfigurability allows it to be used in evaluating user interface structures, and underlying system control structures. It can readily serve as a testbed for many of the issues that will arise during the development of the Open E-Book standard. A planned series of modifications will enhance its usefulness for testing and measurement, and permit it to be used for analysis of future generations of electronic book reader devices. The test and measurement capability has already been used on an informal basis during the development of the Janus prototype itself; the testbed now stands ready for formal testbed application.

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